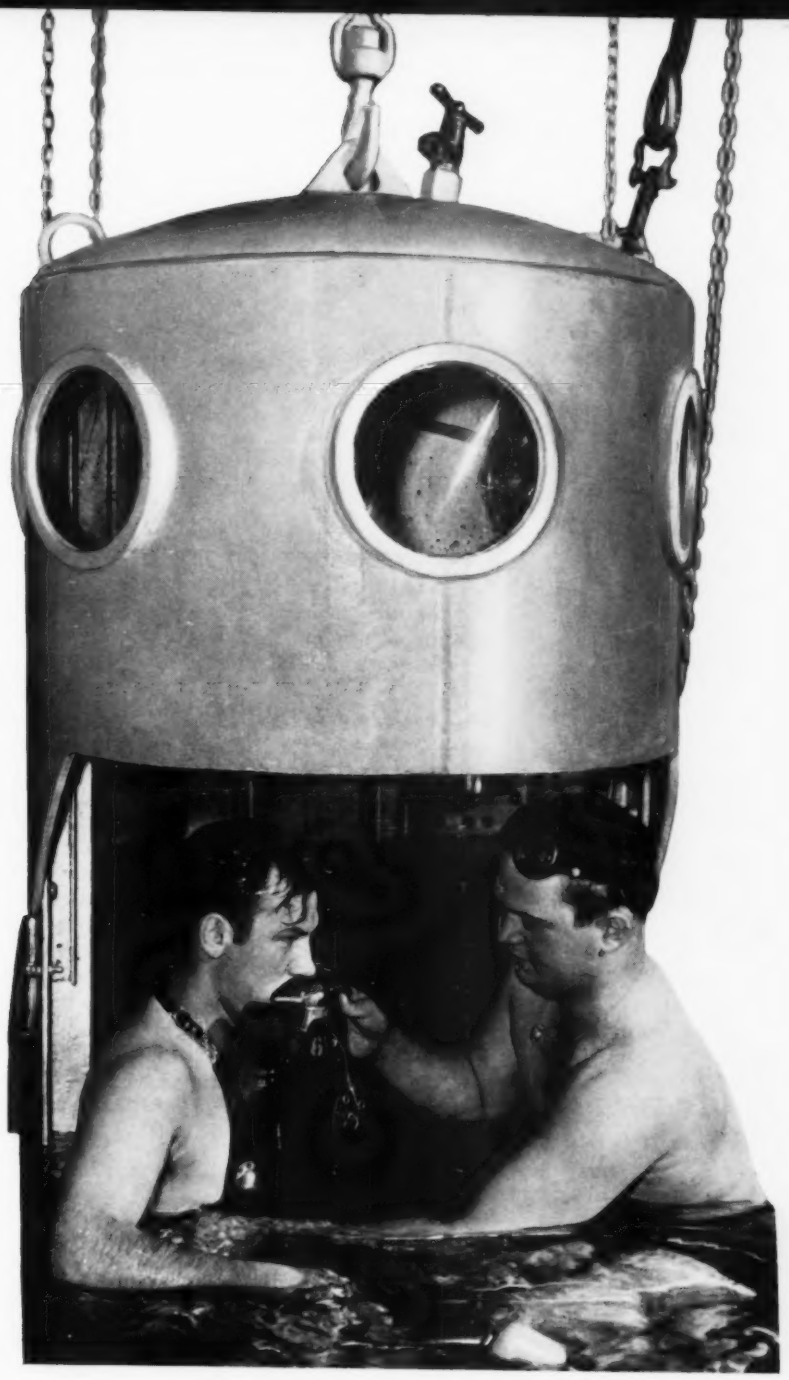
# ENVIRONMENTAL



Simulating the Underwater Environment . . . Page 7

# *Quarterly*

SECOND QUARTER 1956

# Letters to the Editor

In running environmental tests, the effect of the rate of air flow over the equipment is often neglected. In many military specifications, the effect of air flow around the equipment is ignored or the specifications so worded that considerable air flow is required. The environmental equipment manufacturer sometimes produces a small hurricane in order to meet his customer's requirements for a small temperature gradient throughout the chamber.

This results in an environment different from that encountered in service. When a cold climate is being simulated, the environmental condition is too severe resulting in an overtest of the item. This is not too bad unless as a consequence the equipment is drastically over-designed. At high temperatures, however, the items under test often experience a much smaller temperature rise than they will endure in service.

With high temperature testing conditions becoming more important and more drastic, this situation can no longer be ignored or overlooked. While some engineers are well aware of this problem, it seems to have had little public acknowledgment, and there are still many who do not realize the dangers involved. There have been numerous cases of equipment which has passed high temperature environmental tests without difficulty only to fail miserably in the field because of the condition described above. There have even been cases in which aircraft operating in polar regions have had difficulty with temperature rise conditions because of lack of air circulation and proximity to other heat producing equipment.

What can be done to relieve this situation? Well, if a more wide-spread awareness of the significance of air flow across test items is generated among test engineers, much good will have been done. The following actions might also be taken:

1. Military specifications should include coverage of this problem. This has already been done in temperature rise testing of transformers.
2. Environmental equipment manufacturers should publicly take notice of this problem and provide equipment which will enable the test engineers to produce realistic conditions. For example, maintenance of wall temperatures at controlled temperatures and a wide range of control of circulating air control might help.
3. In running environmental tests, test engineers should use test set-ups that more closely simulate the equipment installation. A physical arrangement similar to the service installation might be used. Instead of placing the equipment in the blast of chamber circulating air, a sheet metal enclosure similar in size and shape to a service installation might surround the test items. The wall of the enclosure would be maintained at the temperature of the environment to be simulated and air circulation inside the enclosure be restricted to the amount normally obtained in service.

If more of us can become aware of the above conditions, we may have fewer unexpected failures in the field and increase the effectiveness of environmental testing.

J. C. WARD
Head, Environmental Testing Section
General Precision Lab., Inc.
Pleasantville, N. Y.

---

The January issue of the *Environmental Quarterly* was my introduction to your publication. The information found therein was a most pleasant surprise. It is hoped that the future issues of this publication will be equally as informative.

My peronal interest, if I may take the liberty of making suggestions, would include a questions column. The questions, it is hoped, will be actual problems encountered in the field, and therefore would be of interest to a majority of the test engineers, either in having an answer, or in needing the answer. My second interest in any publication, and no less so in this one, is a letters to the editor page, or pages. Here is where the individual expresses himself, giving the editor and the officials of the Institute a cross sectional view of the membership as to the membership needs. To the individual member and reader it gives a chance to find out what the fellow member or reader is thinking. A third and final suggestion is an up-to-date and expanded new products section, since most engineers in any field are interested in new items in their particular line. This should in time, with the proper interest, include new techniques, or new approaches to old problems, based on experience rather than theory.

These are suggested as supplements to as many full length articles on industry related subjects as can be accommodated in a magazine of the size intended. I find ads of equipment and instruments, particularly of new items, as interesting most times as articles on test techniques and problems.

LAWSON EXLEY
Test Engineer
Aeroflex Laboratories, Inc.
Long Island City, New York

FIRST CLASS
PERMIT No. 9398
NEW YORK, N.Y.

BUSINESS REPLY CARD

No Postage Stamp Necessary if Mailed in the United States

3c - POSTAGE WILL BE PAID BY –

ENVIRONMENTAL QUARTERLY

30 Church Street

Room 524E

New York 7, N. Y.

## SUBSCRIPTION CARD

Please enter my subscription to the new Environmental Quarterly and bill me at the special introductory rate of $4.00 for the next five issues.

Name: .....

Company: .....

Street Address: .....

City and State: .....

# ALPHA

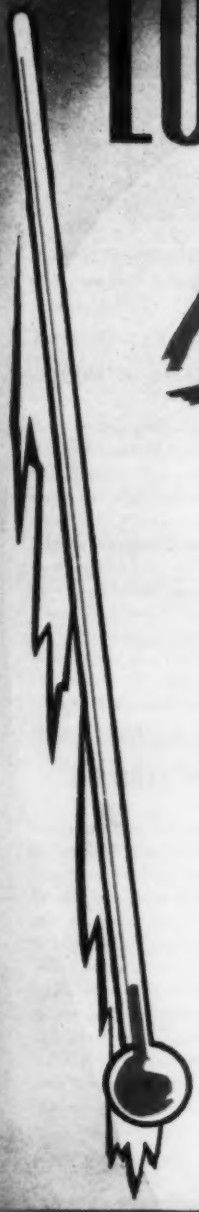
# LOW TEMPERATURE

# *Refrigeration*

*Designed for*

**UNIFORM TEMPERATURE** **MINIMUM FLOOR SPACE**

**RAPID CHILLING** **FULLY AUTOMATIC OPERATION**



**NEW LOW TEMPERATURE TECHNIQUES**

*affect you if you are engaged in the following -*

- ★ Aircraft production and assembly.
- ★ Chemical curing, ageing, and processing.
- ★ Precision gauge manufacture.
- ★ Laboratory testing.
- ★ Biological laboratories and hospitals.
- ★ Storage of annealed aluminum alloys.
- ★ Rubber processers.
- ★ Scientific navigation; aeronautical instruments.
- ★ Tool and fixture manufacture.
- ★ Engine and precision machine manufacture.
- ★ National physical health service.
- ★ Scientific and fundamental research.

*And Numerous Other Applications.*

**ALPHA ELECTRIC REFRIGERATION CO.**

1115 EAST SEVEN MILE ROAD • DETROIT 3, MICHIGAN • PHONE TWINBROOK 2-5700

For more information, circle No. 200, page 3.

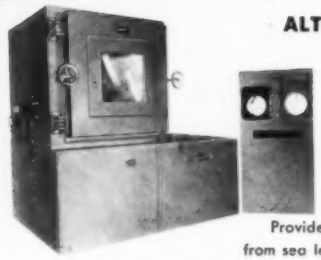
AR★

*for completely AUTOMATIC*

# ENVIRONMENTAL TEST EQUIPMENT

*in any combination*

## ALT SERIES



Provides simulated Altitude from sea level to 80,000 feet or higher, Temperatures from −100° F or lower to +500° F or higher, and Relative Humidity from 20% to 95%. Standard models available with rectangular test space from 5 cu. ft. to 64 cu. ft. Features include air circulation, water cooled condensers, safety thermostat.

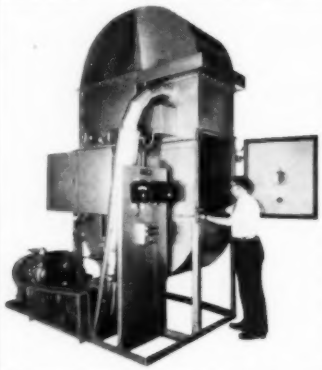
## SO SERIES

For testing under conditions of Temperature (from −100° F and lower to +500° F and higher) with or without Humidity. Completely self-contained unit has hermetically sealed stainless steel test space from 5 cu. ft. to 64 cu. ft. in standard models.

## TO SERIES

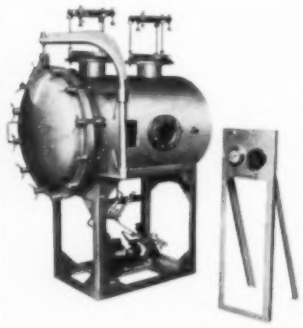
Top opening cabinet for testing, processing or storage at extreme low Temperatures of −120° F or lower. Auxiliary equipment available to produce temperatures as high as +185° F.

## SAND & DUST



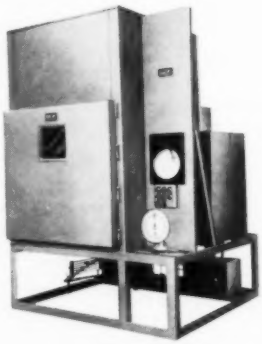
For testing under conditions of Sand & Dust, standard chambers are supplied with test space from 8 cu. ft. to 80 cu. ft. Streamlined design minimizes air side pressure drop. Furnished complete with initial dust supply, factory preset air velocity, and temperature, humidity, air velocity and dust density indicators.

## EXPLOSION



The safest chamber available for testing under conditions of explosive atmosphere from sea level to 50,000 ft. Features include air movers to assure adequate circulation of vapors, dual automatic pressure release valves for double the required relief area and complete ignition system, including remote firing station.

## RS SERIES



For testing under conditions of Rain and Sunshine. In Sunshine Test, provides radiant energy of 100 W to 140 W per sq. ft. with temperature maintained at 45° C. In Rain Test, water is emitted in small drops at rate of 4 inches ±1 in. per hour, with temperature maintained between 11° C and 20° C. Chamber temperature maintained between 20° C and 30° C.

Also manufacturers of Fungus, Central Brine, Special Liquid Chilling and other types of Environmental Test Equipment.

## AMERICAN RESEARCH CORPORATION

22 BROOK ST. • BRISTOL, CONNECTICUT

★

## Sander Calls Science Meeting A Success

**Future of Science Section Brightens As Over 300 Attend 2nd Annual Meeting**

Registration at the Annual Meeting of the EEI Science Section rose from about 160 in 1955 to approximately 330 at the Second Annual Meeting held in Chicago April 19th and 20th, according to Henry F. Sander, of Vapor Heating Corporation. Mr. Sander was chairman of the committee that planned and organized this year's affair.

In Mr. Sander's opinion, this extraordinary attendance has made the Second Annual Science Meeting an outstanding success. The obvious conclusion to be drawn from the size of the meeting is that a crystallization of interest in the long-range purposes of the Institute is occurring on a broad front.

More complete coverage of the Second Annual Science Section Meeting will appear in the next issue of the *Environmental Quarterly*, presently scheduled for July delivery. It is expected also that a publication date for the voluminous "Proceedings" of the annual meeting will be firmed up in time for announcement in that issue.

## Mattingley Appointed Quarterly Editor

Ray H. Mattingley has been appointed editor of the *Environmental Quarterly*, according to an announcement at the Second Annual Science Section Meeting in Chicago by George D. Wilkinson, General Manager of the Environmental Equipment Institute. Mr. Mattingley will assume full responsibility for production of the *Quarterly* commencing with the July issue.


# ENVIRONMENTAL *Quarterly*

VOL. 2, NO. 2 2ND QUARTER, 1956


TABLE OF CONTENTS


Methods of Simulating the Underwater Environment *by Hilbert Schenck, Jr.* ..... *Page 7*

Design of Vacuum Equipment *by David Ettelman* ..... *Page 11*

New York Meeting ..... *Page 25*

New Products ..... *Page 13*

New Literature ..... *Page 19*

Questions and Answers ..... *Page 17*

Letters to the Editor ..... *Inside Front Cover*



ENVIRONMENTAL QUARTERLY published four times each year by the Environmental Equipment Institute, 30 Church Street, New York 7, N.Y., George D. Wilkinson, General Manager. Subscription rate: $4.00 per year.


The *Environmental Quarterly* does not pay for manuscripts it publishes. It solicits voluntary submissions of articles of general and technical interest. All manuscripts must be accompanied by a brief biography of the author and a statement of his present business connection. Illustrations should be either black line drawings or glossy photographs. Unacceptable manuscripts will be returned to the authors.

FOR MORE INFORMATION on products described in this issue, "circle" the key number and mail this coupon to the editor, *Environmental Quarterly*.

| | | | |
|---|---|---|---|
| 200 | 230 | 260 | 290 |
| 210 | 240 | 270 | 300 |
| 220 | 250 | 280 | 310 |

Name _____

Title _____

Company _____

Address _____

City & State _____

No. of Employees in Firm _____

Type of Business _____ 2nd Quarter, 1956

BEMCO STANDARD AND CUSTOM BUILT ENVIRONMENT TEST EQUIPMENT

**W** Series

**LOW COST HIGH HUMIDITY TEST FACILITY**

Specifically designed for high humidity testing in accordance with MIL-E-5272-A, Procedure I and 3.

| Model | Test Space |
|---|---|
| W-8 | 24"x24"x24" |
| W-27 | 36"x36"x36" |

**WF** Series

**TEMPERATURE AND HUMIDITY CHAMBERS**

Dry bulb temperature range from —100 F. to +500 F.

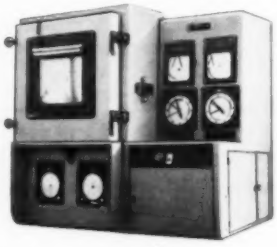
With or without controlled humidity is now available in a standard unit.

All heli-arc welded stainless steel interiors.

**WFA** Series

**STANDARD ALTITUDE CHAMBERS**

Temperature:
—120 F. to +300 F.
Relative Humidity:
20 to 95%
Altitude:
Site to 150,000 Feet
Using Compound Freon 22 or Cascade Freon 13 systems welded and pressure checked inner and outer liner to insure vapor proof seal.

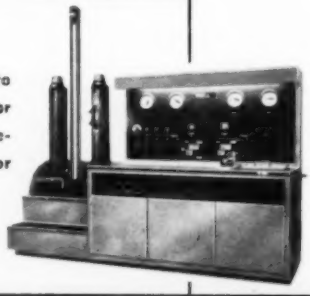


**DF** Series

**DRY ICE CHAMBERS**

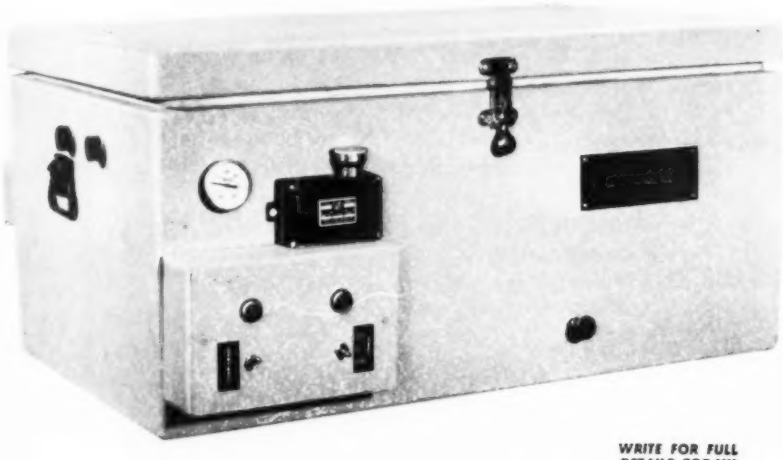
These units are designed for high performance in the variable range of —100 F. to +200 F., are available with or without relative humidity.
Capacity of dry ice section is sufficient to hold —100 F. test temperature over a week-end.

**We will design to your specification or fabricate to your design any hydraulic or pneumatic bench equipment.**



# DRY ICE, HIGH AND LOW TEMPERATURE CHAMBER

## BEMCO MODEL EDF-100-1



***WRITE FOR FULL DETAILS TODAY!***

Small, portable, accurate
high & low temp. testing box

Mass production from special dies.
Immediate delivery from stock.

Designed for the individual engineer:
Does not tie up your larger equipment.

Holds a 50-lb. block of dry ice.
Is ducted to balance heating and cooling
without wasting dry ice.

Temp. range: —100 F. to +200 F. control ± 2 F.

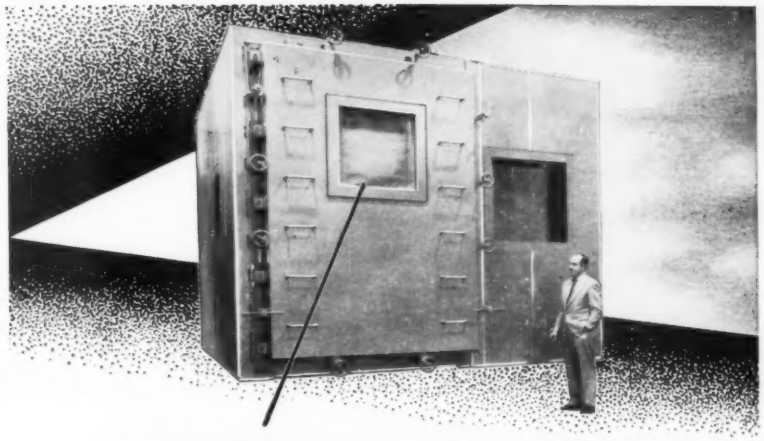
Wt. 60-lbs. uncrated.

Test space: 10" long x 17" wide x 11" high.

Overall dimensions: Length, 20" plus motor
Width, 32"
Height, 16½"

**BEMCO, INC.** 11111 CHANDLER BOULEVARD NORTH HOLLYWOOD, CALIFORNIA

For more information, circle No. 220, page 3.



# "EXTRAS" ARE STANDARD WITH BOWSER

Bowser test chambers have the engineered "extras" as standard equipment. Bowser engineers have designed their units with your needs in mind.

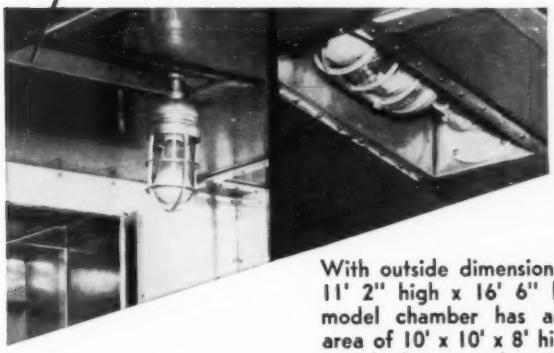
Consider, for example, lights in the Bowser high altitude chamber shown above. They are swivel type for convenient operation . . . vapor proof and recessed in stainless steel to permit full utilization of test area.

Performance characteristics of this Bowser chamber include:

Temperature range from —100°F to 185°F.

Altitude simulation up to 85,000 feet.

Evacuation rate of 5000 F.P.M.



With outside dimensions of 13' 2" wide x 11' 2" high x 16' 6" long, this standard model chamber has an interior working area of 10' x 10' x 8' high. Door is 5' wide x 8' high, its window 30" x 30", and wall window 36" x 36".

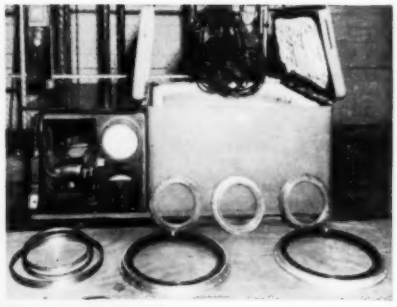
Whatever your needs in environmental test chamber equipment . . . high altitude, humidity, sand and dust, explosion, non-magnetic, etc. . . . check with Bowser, the pioneer.

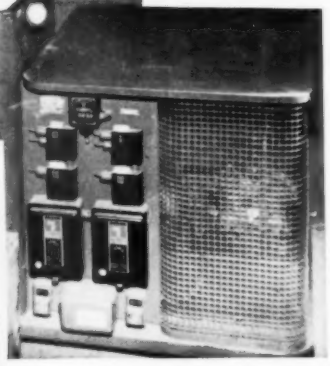
BTR

BOWSER TECHNICAL REFRIGERATION

DIVISION BOWSER INC TERRYVILLE CONNECTICUT

For more information, circle No. 230, page 3.





**HIGH PRODUCTION CHILLING**

Shrink-Assembly; Complete stabilization of steel through 100% transformation of austenite to martensite; Tool steel treatment for increased hardness, strength and ductility; Seasoning gauges, etc.

# *Maximum* CAPACITY... *Minimum* SIZE... *for* low-cost production chilling

**LABORATORY UNIT**

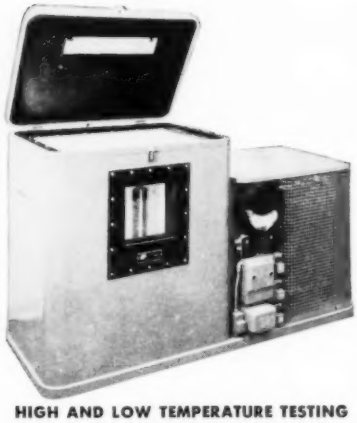
Model A-120-2. 2 cubic feet chamber size, with thermal capacity of 400 B.t.u.'s per hour at —120° F.
For testing and storage at low temperatures . . . experimental applications where moderately small capacity is needed.

**PROGRAM TESTING**

Specially-built, custom-designed units for specific programs, including hot and/or cold cycling under various pressures and selected conditions. Fully automatic controls. Completely flexible. Many combinations at preset time intervals.

**ALTITUDE CHAMBERS**

Complete line for simulation of any combination of conditions. High and low temperatures, varying relative humidities, altitudes up to many thousands of feet . . for product or packaging tests under special conditions.



**HIGH AND LOW TEMPERATURE TESTING**

Low temperature units may also be equipped with accessory devices for temperatures as high as +250° F. for alternate processing or testing of high and low temperature within a single cabinet. Provisions for higher temperatures can be supplied.

**Write TODAY for Complete Line Catalog #102**

## Cincinnati Sub-Zero Products

*General Offices and Plant*
Reading Road at Paddock Cincinnati 29, Ohio

**Member Environmental Equipment Institute**



For more information, circle No. 240, page 3.

By HILBERT SCHENCK, Jr.
Pratt and Whitney Aircraft Company

# METHODS OF SIMULATING THE UNDERWATER ENVIRONMENT

## HISTORICAL INTRODUCTION

Laboratory simulation of the undersea environment has played a vital part in the design of diving and salvage equipment and in the study of the physiology of high pressures. The great French physiologist Paul Bert recognized the need for controlled tests on laboratory animals. He was using both high pressure and altitude chambers during the last half of the nineteenth century (1) and from this work evolved many basic theories of respiration in abnormal pressure regions. Later, J. S. Haldane of England, using a large steel chamber at the Lister Institute, ran tests on men and goats in artificial atmosphere exceeding eighty pounds per square inch thereby simulating, from the standpoint of pressure only, a depth of two hundred feet of sea water (2). From these simulated dives to great depths, Haldane derived a series of 'decompression tables' that would permit a diver to ascend after work on the bottom in such a manner that nitrogen dissolved in his tissues would freely exit to the blood and lungs rather than causing circulation blockage and injury, the disease known as 'Bends' (3).

British interest in the subject remained high and work continued with air-filled pressure chambers and with water filled chambers having an upper air space on which the pressure could be varied to simulate not only the pressure of great depths but the actual presence of water as well. The firm of Siebe, Gorman and Co. and particularly its managing director, Sir Robert Davis, pioneered in this work using a variety of these wet and dry chambers and Davis developed a number of useful underwater devices, most notably, the Davis Submarine Escape Lung. The United States, with military research cut back following World War I, showed less interest in laboratory development of undersea devices and techniques, even though Navy divers had successfully completed the deepest salvage job ever attempted, the raising of the submarine *F-4* sunk in 306 feet off Honolulu. In 1927 the submarine *S-4* was rammed and sunk in 102 feet of water off Provincetown on Cape Cod. Through a tragic combination of bad weather and poor judgment several crew members gradually suffocated while rescuers

*(Continued on Page 8)*

*(Numbers in parentheses apply to references at end of article.)*

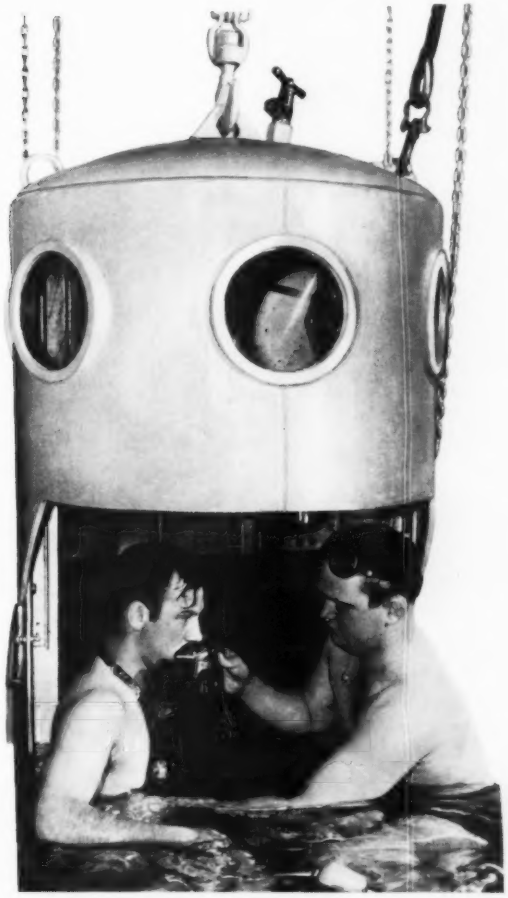


*Fig. 1*

*A surface view of the submarine escape training tower at New London. The instructor is teaching a trainee on the use of the Momsen Lung. The small diving bell is suspended within the trunk of water to provide an air space at any desired depth. (Official United States Navy Photograph)*

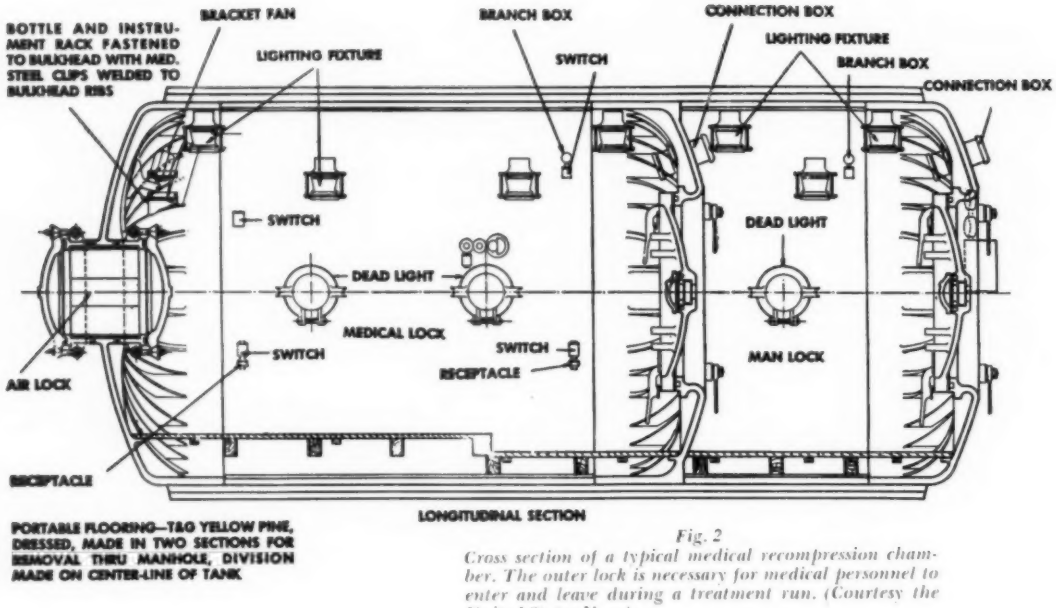



*Fig. 2*

*Cross section of a typical medical recompression chamber. The outer lock is necessary for medical personnel to enter and leave during a treatment run. (Courtesy the United States Navy)*

## METHODS OF SIMULATING THE UNDERWATER ENVIRONMENT

vainly struggled above. The resulting outcry from Congress and the public resulted in a concerted program of research that has never halted.

The most ambitious project in this new era of subsurface research was the construction of a 140 foot tower in New London. In this tower, trainees can enter at the bottom and simulate an ascent from depths in excess of one hundred feet, using escape breathing apparatus. Accidents in the tower during the nineteen-thirties uncovered another diving disorder of great menace. A trainee, unfamiliar with the water and diving equipment, might hold his breath during a portion of the ascent. As he did this, the air trapped in his lungs would expand and force great bubbles into the heart, resulting in almost instant death in some cases. The reward for work in this and other facilities came in 1939 when thirty-three men were saved in the *Squalus* disaster (4).

During this period, work was performed by the Navy and in University laboratories investigating the gas, helium, as a substitute for nitrogen in normal air. Many tests were run on animals using a variety of small pressure chambers to simulate depths in excess of six hundred feet, and decompression tables for use with helium 'air' were drawn up (5). Wet and dry pressure tanks and open tanks were built at the Navy Diving School in Newport, R. I., and at the experimental diving unit at the Washington Navy Yard. The Bureau of Mines Experimental Station in Pittsburgh was also active in much of the animal experimentation with helium.

Following World War II military and civilian interest in diving and the undersea became more marked. Underwater Demolition Teams rapidly expanded and the French development, the 'Aqua-Lung' interested many people in sport diving in shallow water. In the rush of commercial exploitation of this sudden demand, little testing or research has been accomplished, but the Navy and the more serious divers still seek equipment that is truly foolproof. While the amount of environmental simulation equipment involved in diving history has been small, it is safe to say that, without it, little of use would have been done.

*Diving—Pressure Simulation Only:* The classic device for basic physiological research at high pressures is the dry pressure chamber. The majority of these chambers now in use have a primary function as an emergency treatment room. If a diver is improperly decompressed during his ascent and suffers pain after leaving the water he must immediately return to a high pressure region. In the early days of diving this meant that he was put back in his suit and dropped over the side onto the bottom. Such a treatment was extremely dangerous if the man was in pain and incapable of controlling his actions. The obvious solution is to provide a comfortable room which can simulate the undersea sufficiently to compress the pain-giving bubbles in his body and allow them to leave his tissues slowly. This is known as 'recompression' and most dry chambers are called 'recompression chambers.' A typical device is shown in Figure 2. Many recompression chambers are also used for research into diving physiology and for training inexperienced divers to undergo rapid pressure changes. Small chambers are often used for animal experiments.

The general requirements of all such chambers are similar as regards gas demand and blowdown capacity. A diver can usually descend at a rate of from ten to one hundred feet a minute resulting in a pressure rise-rate of from about five to 50 pounds per sq. in. per minute. The rise rate in any chamber should be as high as the maximum descent rate would require. Ascents are limited by Navy regulations to twenty-five feet a minute or a pressure decrease of about 12 pounds per sq. in. per minute. with an emergency rate fixed at twice this (6). Blowdown must, of course, be perfectly controllable for too rapid a pressure drop will cause explosive decompression with its attendant dangers (7).

Large U. S. Navy chambers have maximum operating pressures of 350 pounds per square inch and are tested at 525 pounds per square inch before use (5). Medical treatment tanks must be capable of sustaining a pressure of 105 pounds per square inch but need not go higher. Further increase in treatment of the Bends does not decrease the pain-giving bubbles to any extent.

Operating procedures are variable and dependent on the needs of the moment. Should a man suffer a severe case of bends he would be rushed to the chamber, placed inside with a medical officer, and placed under high pressure as rapidly as possible. Long periods of slow pressure reduction might follow and all food and drink would have to be passed in through a pressure lock. A more relaxed procedure is followed in testing diving and submarine trainees (8). Here the candidates are seated inside and the pressure raised to perhaps fifty pounds per square inch in ten or fifteen minutes. The rate of increase will often be controlled by an instructor who is inside where he can watch the reaction of those undergoing the test. Scientific research with pressure chambers requires carefully controlled atmospheres, a variety of measuring instruments, and good visibility between inside and outside.

*Diving—Complete Simulation:* All medical treatment needs can be met by dry tank work, but before new equipment or techniques can be fully trusted in the open sea, they must be checked in a wet tank. The simplest form of wet tank is simply a cylindrical tank perhaps twelve feet high and ten to twenty feet in diameter, filled to the brim with water. Such a test room is relatively cheap to make and easy to use, but it cannot simulate the effect of pressure at depths greater than the actual tank depth. The obvious extension of the small tank is to make it larger and taller until the desired depth and pressure is obtained. This was done at New London with the 140 foot diving tank at the submarine base. Although this huge, water-filled cylinder was intended to train submarine crews in escape methods, it has been used for various diving studies and is currently occupied in underwater demolition team training. Such a large installation is costly but it most closely approaches the conditions of the open sea.

An easier way to duplicate the conditions of the sea bottom is to cover over the top of a wet tank and pressurize it. Such a pressurized, water filled chamber was

*(Continued on Page 10)*

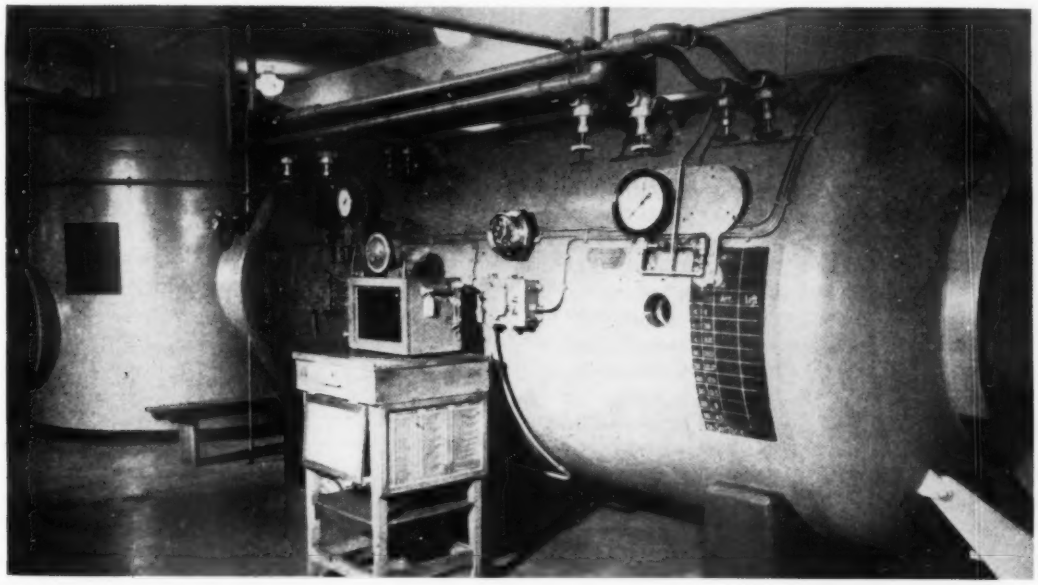


*Fig. 3*

*A large Navy dry test tank for medical research and equipment development. Notice the diving telephone amplifier on the small table, the prominent clock for checking times of personnel inside, and the several pressure gages. (Courtesy the United States Navy)*

## METHODS OF SIMULATING THE UNDERWATER ENVIRONMENT

*(Continued from Page 9)*

first suggested by Davis and several closed tanks are now found in the United States as well as England. Tests on equipment for diving, cutting, welding, and other undersea jobs are performed in water at various simulated depths. The main disadvantage of such a unit is apparently a psychological one for Davis notes that many divers suffer from claustrophobia during tests and refer to the Seibe, Gorman installation as the 'chamber of horrors.' It is obviously desirable to make any test tank as large as possible if training of men is to approach the prototype conditions.

The conduct of wet tank tests usually approximates standard methods of open-sea diving. The diver descends into the tank, tended or watched by men on the surface. He works in the normal manner, carrying out whatever equipment tests or training activities were prescribed. Telephone communication is often maintained since speech from water out to the open air is impossible. In the case of the pressurized wet tank, the diver is always accompanied into the pressure region by at least one tender who may sit over the water surface and give aid in case of emergency. Of all the simulation gear used in diving, this pressurized wet tank requires the most care in its use, for any sudden pressure increase may squeeze and kill the diver. Only expert men work in such a unit and the outside personnel must be thoroughly competent and familiar with the pressurizing systems. Simulated wet tank dives in excess of three hundred pounds per square inch or 650 feet of water have been safely made (9).

*Other Activities—Complete Simulation:* Aside from tests of men and diving equipment, there are many other undersea problems that can be worked out using small pressurized wet tanks. As an example, Figure 4 shows a typical underwater camera design that might require pressure testing in water, either as a quality control measure during manufacture or during initial design stages. A small wet tank pressurized from a compressed gas source answers the need perfectly, and if properly designed this tank could rapidly test a series of such articles before they were released for sale. By alternately pressurizing and blowing down the test tank a service life test could be performed in a few hours to establish whether the joints and stuffing boxes of the camera case would work loose after repeated dives. Various other small instruments for use underwater could also be tested in a wet tank such as strobe light equipment, waterproofed temperature and salinity measuring devices, hydrophones, and a host of similar tools.

Certain biological studies could be performed in pressurized aquariums if such were made available. High pressure chambers have been used to keep alive microorganisms from the great depths of the ocean (10). In

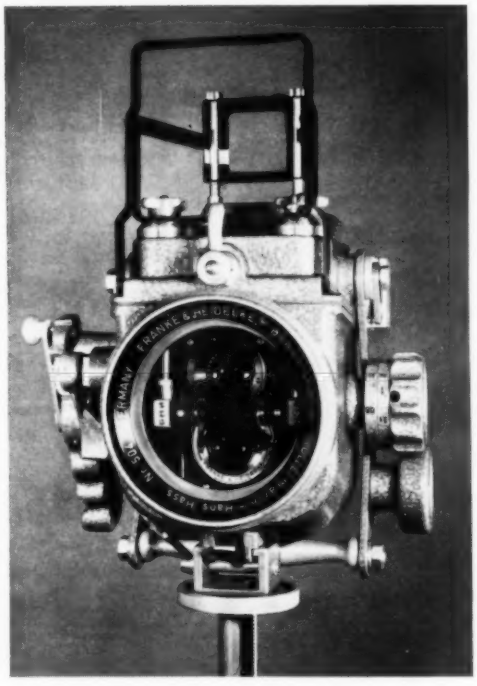


*Fig. 4*

*The Rolleimarin camera case designed by Dr. Hans Hass of Germany is a typical underwater device that must be leaktight under all design conditions. (Courtesy the Fenjohn Underwater Photo and Equipment Company)*

such simulation attempts, not only the pressure must be duplicated but the temperature, salinity, and biological nature of the water as well. There is great interest among some marine biologists as to the depth ranges of certain fish, and the adaptability of fish to depth variations. A moderate sized tank having good windows and full pressurization equipment would open interesting doors, but little has been done along this line as yet. The design problems of such a chamber are challenging.

Every tropical fish aquarium is actually a fairly complex environmental simulator, in which water purity, food supply, temperature, and dissolved oxygen concentration must be kept in balance. The most ambitious attempt of this sort is quite obviously Marineland in Florida, which has two large tanks in which many species of fish live together in a balanced ecology. The design and operation of such large aquariums require full liaison between chemists, biologists, and engineers.

*(Continued on Page 23)*

# DESIGN OF VACUUM EQUIPMENT

By DAVID ETTELMAN
Tenney Engineering, Inc.

**With what environmental conditions do we associate vacuum? The condition which immediately comes to mind, and is the one which is of chief importance, is that of high altitude. Here the rarefied air is at an effective pressure lower than that of the atmosphere at sea level. But we can say this in another way and show the relation of vacuum and pressure; that at any altitude higher than sea level a vacuum exists, the degree of vacuum depending upon the extent of altitude under consideration.**

Remembering that sea level is equivalent to zero altitude, and that by definition "atmospheric pressure" is that which obtains at sea level, further clarification can be made. The atmosphere enveloping the earth is well over 40 miles in height, and because of the earth's gravitational attraction for it, the atmosphere, which has weight, is kept around the earth. As a result of the earth's attraction for the atmosphere, the air nearer the earth is compressed by the weight of the air above it, becoming more dense as the altitude is decreased, finally arriving at the density associated with atmospheric pressure, at sea level.

It can then be seen that as stated before, altitude may be described in terms of absolute pressure, where atmospheric pressure at sea level is determined experimentally to be approximately 14.7 pounds per square inch.* Then as the altitude is increased, the pressure decreases until at some extremely high altitude the pressure approaches zero. Or it may be described in terms of vacuum, considering sea level (atmospheric pressure) as reference pressure (zero), and the degree of vacuum becoming greater as the altitude is increased and the air becomes rarefied.

**The United States Standard Atmosphere takes this value at sea level at 58.7°F (518.4°R). As the altitude increases, in addition to the pressure changes mentioned above, the temperature begins to fall. Thus a given altitude can have a particular temperature associated with it as well. Obviously, from summer to winter, or for that matter, from one time of the day to another, temperature changes cause the temperature values for any specific altitude to vary. Also, this causes air density fluctuations and therefore the pressure can change at any specific altitude because of temperature changes. The United States Standard Atmosphere (and its Extension) is described by a compilation of these values at different altitudes (based on the 58.7°F sea level temperature) as a result of much scientific work and experimentation. For convenience and uniformity, the properties of the United States Standard Atmosphere are used for environmental testing purposes.*

It is hoped that the word vacuum, in the sense that it is to be used here, has been fully defined, and that it can be employed to describe a vacuum of any degree from only partial (slight emptiness) to extremely high (virtually complete emptiness) and that the vacuum may be measured in terms of vacuum or absolute pressure units (the latter being more customary) without being a source of confusion.

The way in which vacuum equipment will be treated also requires an explanation. Equipment used to simulate altitude conditions, usually thought of as a unit, may, however, be considered in two parts. These are the altitude test chamber proper, and the vacuum apparatus.

This article will discuss the necessary vacuum apparatus and auxiliaries up to and including the vacuum line to the chamber, plus some of the more basic instruments.

## TYPES OF EQUIPMENT AVAILABLE

Although a great variety of vacuum pumps are available in the market, generally, for environmental testing purposes, the choice is limited. For such work, rugged design and construction coupled with low maintenance requirements are the main prerequisites. In this respect, environmental test equipment compares closely with industrial vacuum process equipment. Although to some extent this is also true of research and laboratory equipment, the volume of the average vacuum or altitude chamber far exceeds that of most laboratory vacuum systems. This means that the many forms of small (although excellent) pumps that are used for small scale experimental work, chiefly with static, glassware systems, cannot be used for altitude testing.

Of the pumps applied to industrial vacuum systems, only the two general mechanical types, reciprocating and positive displacement rotary, appear to meet the requirements of environmental test equipment. Their single stage volumetric efficiency is about the same (approximately 90%) to altitudes of 15,000 to 25,000 feet (approximately 400 to 300 mm. Hg absolute). However, here the reciprocating pump's efficiency begins to fall off sharply and obviously is a poor choice for use at higher vacuums for this reason. Meanwhile, the rotary pump's efficiency curve has only a small slope and still shows at least 75% efficiency at 80,000 feet (approximately 20 mm. Hg absolute), a vacuum which is virtually unattainable with a single stage reciprocating pump.

*(Continued on Page 12)*

## DESIGN OF VACUUM EQUIPMENT

*(Continued from Page 11)*

For the various reasons given, then, of the vacuum pumps available, positive displacement rotaries are the choice for environmental testing purposes. As it happens, the term "positive displacement rotary" covers a great deal of ground, there being numerous excellent rotary pumps of different design to choose from. All operate, however, on the same basic principle: By means of an eccentric arrangement of a cylindrical rotor in a larger diameter cylinder, as the rotor revolves almost in contact with the cylinder walls, air is drawn in, compressed and discharged. This is accomplished by means of a vane, or a number of vanes which either revolve with the rotor, or bear on it as it revolves.

When a higher vacuum is required than is practical to attain with a single stage rotary pump, a two stage rotary is used. This is merely two single stage pumps arranged in series, where the first pump discharges into the second pump, which in turn discharges to the atmosphere. Such two-stage pumps can either be arranged integrally in one pump body, or be two separate pumps properly piped together. In the event that a still finer vacuum is required, an oil diffusion pump may be resorted to. These pumps can only function at extremely high vacuums and their discharge or fore-pressures should be a few hundred microns or less for best operation. Therefore, a roughing or forepump such as one of the rotary type discussed above is used in conjunction with the diffusion pump. However, requirements for altitudes in the order of 300,000 and 350,000 feet, which requires diffusion pumps, are not common. Also, since these pumps require special consideration in their choice, considerable precautions in their use, and special altitude chambers in most cases, discussion here will be limited. Suffice it to say that the diffusion pump differs from the pumps previously considered in that it is not a positive displacement type, not even being a mechanical pump, functioning rather by directing the molecules of air from the chamber to the forepump by means of the heavy vapor from a heated pool of oil.

### METHODS AND MATERIALS OF CONSTRUCTION

In general, it can be said that many of the methods and much of the material used in the refrigeration industry can be carried over into vacuum work as connected with environmental test equipment. As in refrigeration systems, the pumps themselves are normally of ferrous metals, while the vacuum piping is generally brass and copper to provide corrosion resistance, and to promote a tight system through the ease of making brazed or soldered joints. Of course, the interior of the pump is protected by a film of oil, which in addition to providing the necessary lubrication and seal, is corrosion resistant as well.

Threaded joints may be used throughout the system, but brazed or soldered joints are better. A few threaded connections are usually necessary since pumps often have pipe threads at their suction and discharge. However, experience has shown that threads are a source of leaks unless assembled with shellac or glyptal varnish. Ordinary pipe compounds should not be used since they do not harden, and will act as virtual leaks.

Ordinary plumbing valves can be used, except at the highest vacuums. Brass again is a good choice, but bronze is better, since cast bronze is less likely to be porous than cast brass. Packed valves should be installed in a vacuum system the reverse of indicated water flow so that when closed the packing will not be under vacuum. The ordinary water or steam packing can be replaced with twine soaked in beeswax or stopcock grease for reduced leakage. Also, the seat should be replaced with one of softer rubber.

Any joint or fitting suspected of leaking may be painted with shellac or glyptal. Small leaks in piping may be peined with a hammer and tinned.

### INSTRUMENTATION

Instrumentation for vacuum equipment, as with that for other media, can be divided into three main functions: Indicating, Controlling and Recording. These functions may be performed, of course, by separate equipment, or they may all be accomplished by one rather complex instrument. Programming also can be provided, but instances of this on vacuum equipment for environmental testing are quite rare. The basic pressure indicating instrument is the mercury manometer which can assume two forms.

In the first form, the closed manometer, a virtually perfect vacuum exists above the mercury in the closed end while the other end is connected to the pressure to be measured. Starting with this pressure at atmospheric conditions (where incidentally the closed manometer is a barometer and the difference in mercury levels "h" is the barometric pressure measured in terms of the height of a mercury column) and the mercury risen in the closed leg of the instrument, as the pressure is reduced the mercury begins to fall in that leg. The difference in levels of the two mercury columns is the absolute pressure which is normally measured in inches or millimeters of mercury. With the closed manometer, the more perfect the vacuum, the more nearly the two columns equal each other in height.

The second form of mercury manometer is the open type where the leg not connected to the pressure to be measured is left open to the atmosphere. Here the action is reversed from what it was before, since at atmospheric pressure the height of both legs are the same, and as the vacuum is increased, the mercury rises in the leg which is connected to it. The open manometer can be read directly in vacuum, in units such as inches of mercury.

*(Continued on Page 20)*

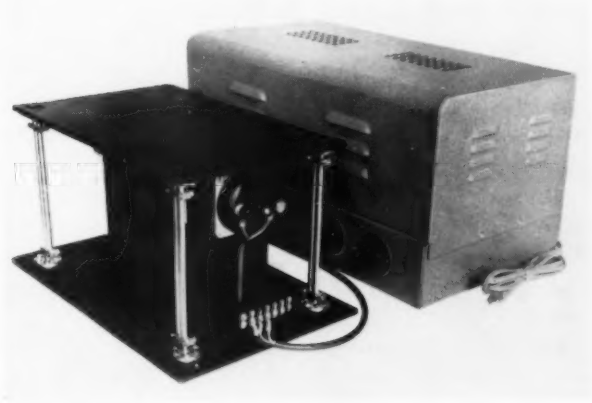
# NEW PRODUCTS

## AUTOMATIC LOCK FOR RIVET REFRIGERATORS

An automatic lock, the positive answer to the control of refrigerated rivet quality, has been developed at the request of Martin manufacturing engineers by the Webber Engineering Corp. of Indianapolis. The non-electrical, thermostatically controlled device locks the refrigerated rivet cabinet when the temperature rises above –10°F. for any reason. Only Quality Control inspectors are furnished keys to unlock the cabinet, and they know that any rivets in a cabinet locked by the automatic device are unsuitable for use and must be reheat-treated. No other employees can open the box, even inadvertently, and take rivets out which have been warmed above specified temperatures.

Settings may be adjusted within wide ranges, but most rivets at Martin are maintained at –20°F with warming above –10°F a critical condition that warrants discarding or reprocessing the rivets.

It is necessary to refrigerate 24ST aluminum alloy rivets to slow the aging process and keep the metal in a ductile, "as quenched" condition so they can be easily headed. At higher temperatures than –10°F, the metal hardens and may crack during the heading operation. Maximum strength is attained when the rivets harden after they have been headed.



## VIBRATION MACHINE

Lance Products announces a new, low cost, 10 to 60 cps adjustable frequency vibration machine which has wide application in the electronic and instrument industries. Among its uses are vacuum tube and instrument stabilization or aging, accelerated life testing, production line inspection for vibration induced noise and intermittent faults, and general vibration testing. It fulfills the fatigue test and low frequency vibration requirements of MIL-E-1B.

The Model AF Vibration Machine consists of an elastically-mounted platform, pickoff, forcing transducer, and power amplifier. It combines high load capacity and low cost because of its unique, self-perpetuating resonant drive principle and provides long and uniform vibration life because all motion is by means of flexing steel members. There are no rotating shafts, bearing, or sliding members to wear or fail.

Frequency range is 10 to 60 cps., maximum load is 70 pounds, and maximum amplitude is 1. inch. A single knob controls the amplitude, and frequency is readily set by adjustable links on the supporting flex members. Power requirements are 100 watts, 115 volts, 60 cycles a.c.

## REFUELING TRANSMITTER

Lynn, Mass., Mar. 8—In-flight refueling transmitters with 50 times the capacity of earlier mass fuel flowmeters are now being manufactured by General Electric's Instrument Department here.

*(Continued on Page 14)*

*(Continued from Page 13)*

The new transmitter—dubbed IFR by the department's laboratory engineers—is designed to measure up to 600,000 pounds of fuel per hour, compared to the 12,000 pounds per hour performance of earlier models.

IFR was developed for the critical mass-measurement of fuel being transferred from tanker planes to bombers and fighters on long-range operations. To meet military environmental specifications the device had to be fast and reliable, as well as rugged and light, said E. E. Parker, department general manager.

The transmitter is mounted in the fuel line leading to the boom which extends from the tanker plane during the refueling process. Weighing only 17 pounds, IFR is "sturdy enough to operate at pressures up to 480 pounds per square inch," Parker said.

"It will stand up to the shock of peak flow surges, including reverse flow—the sucking back of fuel when the boom is telescoped for retraction into the tanker—and perform within one per cent accuracy," Parker added.

Density compensation is not required in the G.E. instrument and it is insensitive to temperature and altitude changes.

A $3,000,000 contract with the Air Force has just been negotiated and shipment of IFR transmitters for use on the KB-50 and KC-135 flying tankers will begin soon.

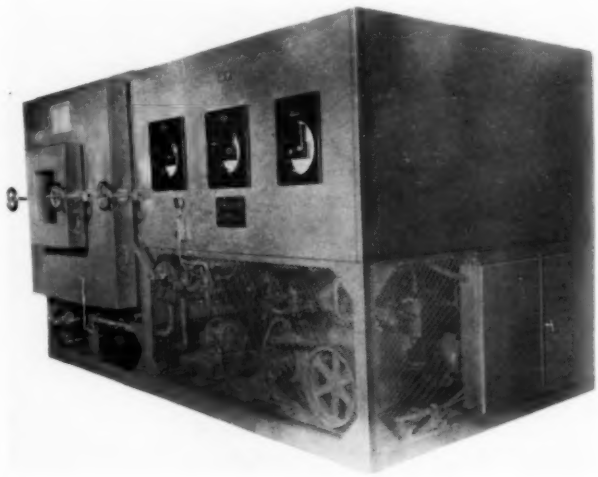
## FOR LIMITED SPACE

This unusual environmental test chamber was designed and built by American Research Corp., Bristol, Conn., to overcome a problem of limited space.

Their customer required that the Altitude-Temperature-Humidity test chamber be installed in a location where there was insufficient room to swing a conventional door open. American Research engineers then developed this overhead type of door which would lift up clear of obstructions.

A special feature of construction is that the air cylinder which raises and lowers the door is counter-balanced, so that in case of air failure the door will not open or close from any position. This affords complete safety for the operator.

Except for the special door, the cabinet is one of American Research's standards, which are available from 5 cu. ft. to 64 cu. ft. It will simulate altitudes from sea level to 100,000 ft., temperatures from –100°F and lower to +500°F and higher, and relative humidity from 20% to 95%.



## ALTITUDE SIMULATION

The extreme high heat developed by skin friction on high altitude missiles has led the American Research Corp., to build the first altitude simulation test chamber with a temperature range of from –100°F to +500°F, without modification.

This unusual chamber incorporates a 64 cu. ft. test space with all of the standard American Research features, including completely automatic operation, air circulation, mercury manometer calibrated in thousands of feet, and a safety thermostat to protect heaters against accidental burnout.

The chamber provides accurate simulation of atmospheric conditions at high altitude near ultra-sonic velocities, and the controls are designed to duplicate the results of rapid changes in acceleration.

# CONRAD, Inc.

## HOLLAND, MICHIGAN

## ENVIRONMENTAL TEST CHAMBERS

**TEMPERATURE CABINETS**

Two Types
"F" Series — Front Opening
"C" Series — Top Opening

Range:
−150° F. to +500° F.

Size:
4 cu. ft. to 72 cu. ft.

**HUMIDITY AND TEMPERATURE CABINETS**

"F" Series — Front Opening

Range:
−150° F. — +500° F.

Humidity:
10% to 97%
Controlable above a 35° F. D.P.

Size:
4 cu. ft. to 64 cu. ft.

**ALTITUDE AND TEMPERATURE CABINETS**

"F" Series — Front Opening

Range:
Temperature:
−150° F. — +500° F.

Altitude:
Up to 125,000 ft.

Size:
4 cu. ft. to 64 cu. ft.

*Write for File Folder*

CONRAD Inc. SUBSIDIARY OF CRAMPTON MFG. CO.

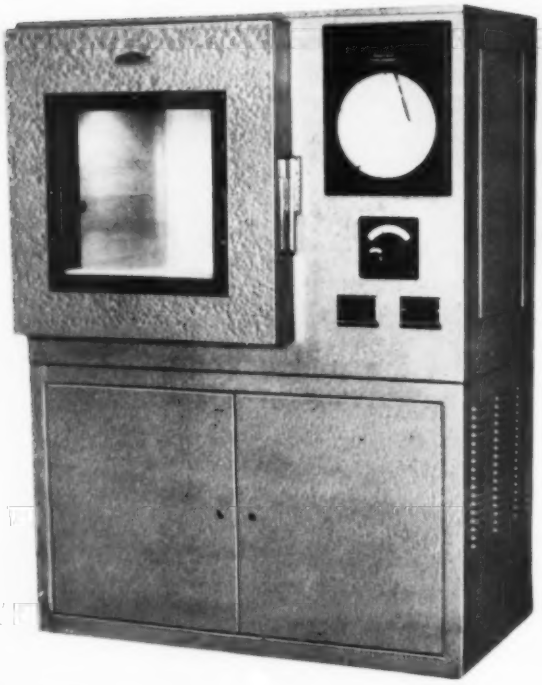
141 JEFFERSON ST., HOLLAND, MICH.

MEMBER OF ENVIRONMENTAL EQUIPMENT INSTITUTE

# CABINET MODEL CHILLING CHAMBERS

*by*

## HARRIS REFRIGERATION CO. inc.



**6 to 50 cubic foot capacity**

**accurate temperature control from -100°F to +200°F**

*Many applications in . . .*

- **LOW TEMPERATURE RESEARCH**
  Component and material studies
- **INDUSTRIAL METAL-WORKING**
  Hardening, stabilizing, and shrink-fitting
- **ENVIRONMENTAL TESTING**
  Prototype and production tests
- **MEDICAL REFRIGERATION**
  Blood and bone storage

*Performance . . .*

The Harris chilling chambers are specially designed for environmental testing. The upright cabinets provide convenient accessibility and observation during tests on small components, instruments, and samples. Chamber temperatures can be held continually at any point within the entire -100°F to +200°F range. Thermostatic control is accurate to ±1°F, and constant temperature is maintained throughout the chamber by a specially designed fan. Temperature pull-down time from ambient to -100°F is 50 minutes. When hot environments are required, temperatures of +180°F can be attained in 30 minutes.

HARRIS

365 WALDEN STREET CAMBRIDGE, MASS.

UNiversity 4-4000



For more information, circle No. 260, page 3.

# *Questions and Answers*

In response to the Questions & Answers section appearing in the Environmental Quarterly dated January 1956, W. S. Osborne, Staff Engineer, Environmental Lab, North American Aviation, Inc., submits his comments relative to methods for cleaning test items which have undergone fungus test, and protective measures for personnel handling the test items.

*"Obviously, autoclave sterilization is not applicable to Electrical, Electronic and Mechanical equipment. Test items may be swabbed with a 50% Methyl-Ethyl Alcoholic solution. The use of an 85% Ethyl Alcoholic solution may serve to increase the membership of Alcoholics Anonymous. A non-metallic brush may be used in conjunction with the alcoholic solution to remove mold growth from areas not readily lending themselves to the application of a swab.*

*"With respect to protective measures for personnel, common sense has no substitute. Soap was used by our ancestors, as a cleansing agent. In this modern age, the function of soap remains the same; with a few beauty aids, deodorants, and perfumes, thrown in, as a gesture of good will on the part of the manufacturer. We never had it so good. We are cleansed, deodorized, and perfumed in one simple operation."*

***Can You Answer This One?***

**"—What are the best practical lines to follow in order to select vibration and shock-mounts for Marine applications according to Specification MIL-T-17.113? Taking into account vibration and shock normally encountered on board warships, should it be considered that the radio set to be protected must be constructed so as to sustain without damage vibration according to MIL-T-17.113 with indicated amplitude on the table (that is to say as if it were fixed on the table without mounting) till 25 cps leaving only to the shock-mounts to insure damping on shocks and vibration above this frequency?**

**"Or is it possible (advisable and useful) to find a solution so as to damp vibration below 25 c/s, keeping good performance on shocks? What are solutions to be preferred and shockmount types to be used?"**

**Submitted by Monsieur A. Desenfant of Sadir-Carpentier, Paris, France.**

## New Building for Los Alamos Scientific Laboratory

Los Alamos, New Mexico, March 22, 1956—Occupation of the new administration and laboratory building of the University of California's Los Alamos Scientific Laboratory has been announced by Norris E. Bradbury, Director of the Laboratory.

Transfer of Engineering Department offices into the new building began the latter part of January, followed by Test Division groups throughout February. Most of the administrative personnel in the Director's office and Documentary Division completed moving this week. When the enormous task of moving is finally completed by other technical divisions and supporting departments, the 560 offices in the new building will be occupied by nearly 1,000 members of the Laboratory staff.

The modern new administration and laboratory building is situated in the Laboratory's new and modern Technical Area across Los Alamos Canyon on South Mesa. Here also are located the new Physics Building, Chemistry and Metallurgy Building, Shops Building, and other new facilities. Except for a few of the old, temporary, wartime structures still remaining on Los Alamos Mesa, the Laboratory has approached the completion of its five-year program of moving its facilities and personnel to its new Technical Area so that it will be completely divorced from the community of Los Alamos.

## Seattle Man Appointed Representative for Cincinnati Sub-Zero

Neil Winikoff, manufacturer's representative, 7554 44th, N.E. Seattle 5, Washington, has been appointed Washington-Oregon Sales Representative for Cincinnati Sub-Zero Products, Cincinnati, Ohio, manufacturers of industrial chilling equipment.

Cincinnati Sub-Zero chilling equipment is used in major metal treating processes for shrinkage of metals preparatory to fitting and assembly; for stabilization and stress equalization of hardened steel tools and parts; and for "cold treating" metal to add to perishable tool life.

Both stock units and special models are manufactured by Cincinnati Sub-Zero Products, ranging in size from 1 cu. ft. machines suitable for laboratory use to 20 cu. ft. models for large capacity.

Among the new products available from Cincinnati Sub-Zero are environmental test chambers for checking product operation and life under varying climatic conditions. The new machines can reproduce any temperature from +200°F. to –150° below zero. They also simulate varying degrees of humidity and air pressures.

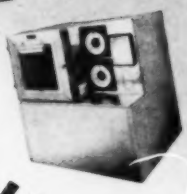
GET YOUR *Free* COPY
OF THIS NEW
CATALOG

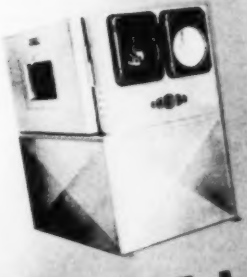
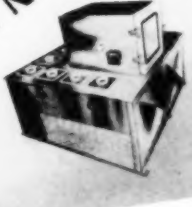
*WRITE • WIRE • PHONE*

# INTERNATIONAL RADIANT CORP.

• ENVIRONMENTAL TEST EQUIPMENT •

VACUUM OVENS
SUPER VACUUM SYSTEMS
ALTITUDE AND VACUUM
ALTITUDE CHAMBERS
HUMIDITY CHAMBERS
DIAPHRAGM EXERCISERS
LOW TEMPERATURES
HIGH TEMPERATURES
AIR CONDITIONING (TEST)
SAND and DUST
LIQUID HOT & COLD BATHS
EXPLOSION CHAMBERS
SUNSHINE CHAMBERS
RAIN CHAMBERS
FUNGUS CHAMBERS
PLASTIC BELL JAR SYSTEMS
SALT SPRAY
SUBLIMATORS
MOBILE REFRIGERATION
IMMERSION TESTS
WALK-IN ROOMS for all environmental tests



MEMBERS: ENVIRONMENTAL EQUIPMENT INSTITUTE
E.E.I

# INTERNATIONAL RADIANT CORP.

4 MANHASSET AVENUE, PORT WASHINGTON, N. Y.

MEMBERS: ENVIRONMENTAL EQUIPMENT INSTITUTE

For more information, circle No. 270, page 3.

# NEW LITERATURE

## Synchronizer for Watching Shake Tests In Slow Motion

Covered in four-page, two-color illustrated brochure which describes how the Slip-Sync automatically synchronizes stroboscopic lights with vibration exciters, thus allowing continuous observation of shake tests in slow motion, or stopped in any selected cyclic position. Special features are indicated, specifications are listed and related equipment is pictured. Chadwick-Helmuth Company, P.O. Box 321, Monrovia, California.

## Mass Flowmeter for In-Flight Refueling

By C. F. Taylor, Instrument Department, General Electric Company, West Lynn, Massachusetts. Fifty Cents per copy—copies will be available until January 1, 1957.

## Expanded Electronics Laboratory

Electrical Testing Laboratories, Inc., New York, N. Y. announces a new bulletin covering its recently expanded electronics laboratory, now equipped to operate in the microwave region.

Consisting of four pages and two gatefolds, the new bulletin lists 39 measurements and determinations which ETL is equipped to make; lists 43 typical electronic items tested; and includes 14 illustrations of various test facilities.

Text outlines benefits to be derived through the use of independent test facilities and briefly covers the four major areas in which ETL's services have been most helpful to industry—the areas of design, development, production and feedback.

Illustrations include views of waveguide testing; electronic timing testing; transformer corona testing; capacitor testing and general views of specialized equipment and overall laboratory facilities.

Copies of the new bulletin may be obtained by writing to Electrical Testing Laboratories, Inc., Two East End Ave., New York 21, N. Y.

CORRECTION: In the Fall Issue of ENVIRONMENTAL QUARTERLY the article entitled "Simple Method Determines Cross Sensitivity in Linear Accelerometers," was credited to Earle G. Foote of the Boeing Airplane Company. Mr. Foote informs us that the paper was written by Erle Malone, an electronic technician in the Instrument Development Unit of the Physical Research Staff at Boeing, Seattle, Washington, who had developed the test method described.

# NEW ENVIRONMENTAL FRONTIERS

Boston, Mass., March 19—Man has finally achieved the first step in unlocking the vast storehouse of energy in the high upper atmosphere.

In a major scientific "breakthrough," scientists of the Air Force Cambridge Research Center's Geophysics Research Directorate have taken the first step in releasing energy chemically stored in the upper atmosphere by the sun.

The scientists, who are doing their work for the Air Research and Development Command, accomplished a breakthrough that has been the subject of speculation by geophysicists for the past ten years.

On Wednesday, March 14, at 1:45 a.m. (Mountain Standard Time), Greater Boston scientists and technicians sent an Aerobee Rocket 60 miles above the desert sands at Holloman Air Development Center, New Mexico.

The Rocket, a type which has been used for several years as an upper atmosphere research vehicle, was equipped to release nitric oxide gas under high pressure into the atmosphere at an altitude of more than 316,000 feet.

When the nitric oxide gas was automatically released, observers saw what first appeared to be the formation of a new star, nearly twice the brightness of the planet Venus.

The light was reported by observers more than 60 miles away from the famed ARDC launching site.

In the space of ten minutes the star had grown in size to approximately four times the diameter of the moon. The brightness of the man made star was roughly half the intensity of the full moon.

By increasing the natural amount of nitric oxide gas in the atmosphere by a factor of several billion, the rocket-released gas was able to unlock the chemically stored sunlight in vast quantities.

This action produced the spot of light in the upper atmosphere which spread out to approximately three miles in diameter before the nitric oxide gas was diluted by diffusion and reduced in intensity.

Nitric oxide gas has the property of bringing two oxygen atoms together to form an oxygen molecule and release light. The gas is not used up in the process, but acts as a catalyst (agent) and is used over and over again without being exhausted.

The process occurs naturally in nature, but the natural abundance of nitric oxide gas is so small that the glow in the sky must be detected at night by instruments many times more sensitive than the naked eye.

Scientists have known for many years that if they could find some way for the separate oxygen to combine together rapidly, a light many times stronger than the natural light in the atmosphere would be emitted.

The experiment may eventually lead to means of extracting energy for such uses as the propulsion of rocket ships high into the earth's atmosphere.

## DESIGN OF VACUUM EQUIPMENT

*(Continued from Page12)*

In either case, care must be taken not to release the vacuum too quickly since rupture of the closed end and loss of mercury can occur in the first type, while loss of mercury from the open type is also likely. Most manometers are constructed with a restriction at the bottom of the "U" tube to prevent such damage, but it is better to play safe than be sorry.

The closed type manometer is preferred for this work since its readings do not require any correction (except for temperature) and are always in absolute pressure with respect to the virtually perfect vacuum above the mercury in the closed end. Since the open type utilizes existing atmospheric pressure for its functioning, it must be corrected for the altitude of the manometer and the temperature and barometric pressure at the time of the test to get absolute values. The mercury manometer may be used satisfactorily down to pressures of one millimeter of mercury absolute.

Other indicating instruments are absolute pressure and vacuum gauges of either the Bourdon or bellows type of construction. These have the objection that like the open manometer, for accuracy, they must be corrected for altitude and barometer. Also, in all but the most carefully made instruments, friction is exhibited, especially on low readings, requiring that the gauges be tapped to eliminate it. Various ranges in these instruments are available to different degrees of accuracy but they at best are not too reliable below five millimeters of mercury absolute.

Controlling instruments vary from the crude vacuum breakers, which are merely relief valves, to very accurate vacuum switches. Both are normally used with an indicator of some sort.

The vacuum breaker balances the pressure difference of the vacuum system to the atmosphere acting on a given area, by means of a spring (which is calibrated only in the higher forms). Trial and error is the usual method of arriving at the adjustment for a given manometer reading.

The vacuum switches employ systems much like the gauges discussed before, and since they are nearly always used with an indicator, they need not be calibrated, just as the vacuum breakers above. If they are calibrated, the correction must be made for the finest work, unless the scale is used only for rough setting and a closed manometer is used for actual pressure determination.

Another arrangement for controlling vacuum, used instead of the vacuum breaker, employs a needle valve intentionally opened to introduce a leak into the system. Here, with the pump running continuously, enough air is bled in to hold the pressure constant at the desired altitude. This again, is of course, a trial and error method. The combination of a Bourdon or bellows type movement with a pen and chart (and a control form) will not be discussed here except to say that a variety of instruments of this type are available to suit different requirements. What has been said of gauges applies here as well, particularly where the presence of pen friction contributes to error.

For the measurement of extremely high vacuums, the McLeod gauge, the one instrument which is most dependable, unfortunately has the drawback that it does not give a constant indication since it operates by taking a sample from the vacuum to be measured. For constant indication specialized instruments which base their operation on the physical properties of low pressure gauges are employed. However, the instrumentation for vacuums below one millimeter of mercury absolute will not be treated any further, since, in the earlier sections, the equipment for creating such vacuums was covered only in generality.


### LET'S INVITE OUR FRIENDS:

THE ENVIRONMENTAL EQUIPMENT INSTITUTE and the ENVIRONMENTAL QUARTERLY are achieving important stature. Undoubtedly, some of the firms with which you do business, and their executives, should be urged to join us. We will be pleased to provide information regarding the Science Section to any firms or individuals you recommend. We will send a copy of the *Quarterly* to all whom you herein suggest:

Name _____ Name _____

Title _____ Title _____

Company _____ Company _____

Address _____ Address _____

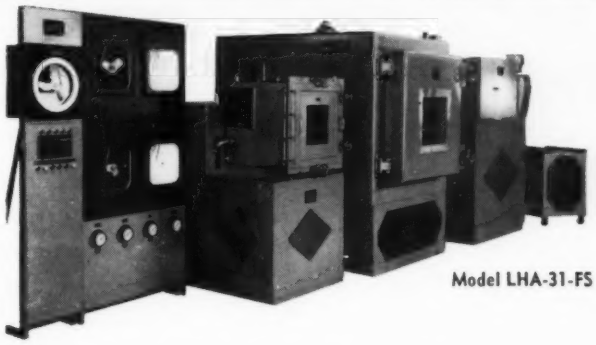
City _____ City _____

Type of Business _____ Type of Business _____

Your Name _____

Company _____

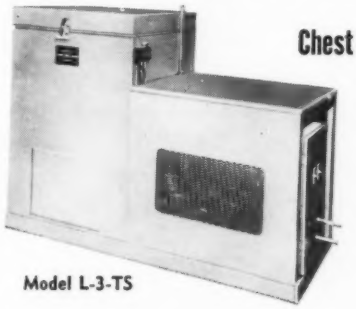
Address _____



Model LHA-31-FS

## High-Low Temperature Chamber with Portable Altitude Testing Section

**Full program control on both temperature and altitude. The 8 cu. ft. altitude test unit is used for ambient altitude testing and can be inserted in the 31 cu. ft. temperature test chamber for low temperature altitude testing. Designed for —100° F. with rapid temperature reduction and close temperature control. Altitude simulation is provided to 200,000 feet with controlled climb and dive. Humidity is controlled from 350° to 175° F., 20% to 95% r.h.**



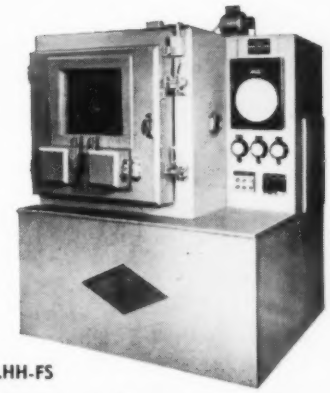
Model L-3-TS

## Chest Type Low-Temperature Cabinet

**Available in sizes from 2 to 30 cu. ft. net working space. Optional controls furnished to customer specifications. Temperature range to —100° F. Capacity for rapid temperature reduction.**

## Low-High Temperature Chamber with Controlled Humidity

**Supplied in sizes from 2 to 100 cu. ft. net working space, these chambers operate to —100° F at rapid reduction rate and provide controlled humidity through a range of 35 to 175° F at 20 to 95% r.h. Full controls available.**



Model LHH-FS

**Equipment available to meet U. S. Govt. specs for environmental testing. Electronic or pneumatic recording or indicating control systems. Walk-in rooms, temperature baths and custom chambers manufactured to specifications. Optional finishes in hammertone, aluminum or stainless steel. Rounded corners standard on all equipment.**

**Manufacturers of Environmental Test Equipment Since 1941**

**MEMBER of Environmental Equipment Institute**

Standard CABINET COMPANY

**57 Washington Avenue**
**Carlstadt, New Jersey**



For more information, circle No. 280, page 3.

# *Better Products with*
# TENNEY-TESTING

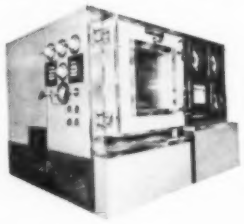
**quality improved — costs lowered by advanced environmental testing**

TEMPERATURE • ALTITUDE
HUMIDITY • METAL TREATING
WALK-IN CHAMBERS
BATHS • SAND AND DUST
EXPLOSION • FUNGUS

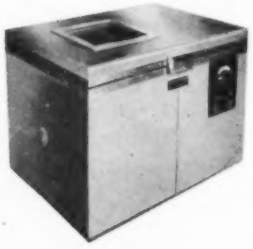
Do your products **really** deliver their rated performances at −100°F... at 150,000 feet altitude... at 95% humidity? Tenney-Testing environmental equipment gives you a complete record of performance under extreme conditions quickly, accurately... eliminates costly engineering and production changes. Environmental testing equipment for simulating **every** atmospheric condition is engineered and manufactured by Tenney. Altitudes to 200,000 feet +... temperatures of −150°F to +500°F... 10% to 100% humidity.

## TENNEYZPHERE ALTITUDE CHAMBERS

Custom-engineered to simulate every atmospheric condition from sea level to 200,000 feet +. Temperature range of −150°F to +350°F.* Relative humidity of 10% to 100%. Full instrumentation for constant conditions or program cycles. Sizes from four cubic feet to walk-in rooms.



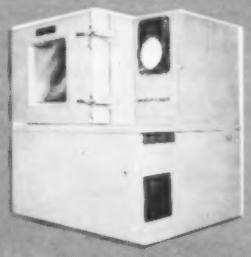
## DRY ICE CHAMBERS



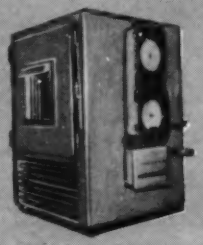
**Low cost** chamber for product testing, storage, and metal treating. Temperature range −100°F to +200°F.* Automatic control, indicating or recording instrumentation. Easy loading and unloading of dry ice compartment.

## TR CHAMBERS

Designed and custom engineered for accurate testing at temperatures of −100°F to +200°F,* with relative humidity 20% to 100%. Recording controlling instrumentation, or program control for MIL specification testing.



## TH CHAMBERS



Precision equipment for accurate testing at above freezing temperatures (+35°F to +200°F*) within a humidity range of 20% to 100%. Available with recording controlling instrumentation, or program control for meeting MIL specifications.

## TENNEY-MITE

New **low cost** mechanically refrigerated test chamber. 1½ cu. ft. capacity, ideal for laboratories, metal working shops, and testing departments. Temperature ranges of ambient to −40°F, −100°F, −120°F. Table-top or free-standing arrangements. Available as a bath, or as an oven to elevated temperatures.

## SUB-ARCTIC CABINETS

For shrink fitting... hardening and stabilizing dies, gauges, and precision parts... research and production testing of electronic equipment, instruments, plastics, lubricants, etc. Wide variety of sizes, with temperature ranges of ambient to −170°F.

Thousands of Tenney Chambers are now in use. Tenney's highly-specialized engineering and design staff — largest in the industry — will analyze your testing problems and develop the most effective solutions.

Write or wire **today** for complete specifications, performance data and quotations on these units or other environmental test equipment.

**Member of Environmental Equipment Institute**

***Engineers and Manufacturers of Refrigeration and Environmental Equipment***

**Tenney**
**ENGINEERING, INC.**
Dept. EB-6 1090 SPRINGFIELD ROAD, UNION, N. J.
Plants: Union, N. J. and Baltimore, Md.

*Higher and/or lower temperatures available.

107

For more information, circle No. 290, page 3.

## METHODS OF SIMULATING THE UNDERWATER ENVIRONMENT

*(Continued from Page 10)*

Water tanks are occasionally used in underwater explosion studies and the important problem in this type of work is obtaining optically clear water so that photographs can be taken (11). Another underwater activity that requires water clarity is the use of water for shielding nuclear events. Observation is of primary importance and water treatment to insure proper transparency is a subject that requires further work (12).

The simulation of conditions around an underwater vehicle or projectile are duplicated in water tunnels. These are usually closed loops of pipe having a circulating pump, straightening vanes, and a venturi at whose throat is placed the test model.

### MATERIALS AND DESIGN OF UNDERWATER ENVIRONMENTAL EQUIPMENT

The designer of wet and dry pressure chambers has a large backlog of data on which to draw. These chambers are basically unfired pressure vessels on which design codes are well established (13). Naturally, those chambers in which human beings will be placed must be highly safety factored and their construction undertaken with care.

The size of a wet or dry test chamber will depend on the use to which it will be put. The useful interior volume might vary from one to many hundreds of cubic feet. The designer must closely anticipate the ultimate service so that he can eliminate bothersome internal projections and place the interior equipment in convenient places. Generally speaking, each chamber is a special job and obtaining complete information on its ultimate service at once will eliminate costly and troublesome changes later.

### AUXILIARY EQUIPMENT AND INSTRUMENTATION

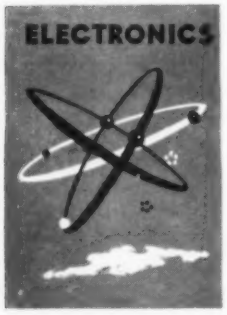
Aside from the basic test chamber, certain other equipment must be supplied for satisfactory operation. Most important is the gas system which will be used to raise the chamber pressure and supply the occupants, human or animal, with respirable gas. A large chamber having an internal volume of perhaps one thousand cubic feet may require a ten fold pressure increase within five minutes. Nine thousand cubic feet of gas must be added at an inlet flow rate of 1800 cubic feet a minute. Such an air demand could be supplied from a compressor, but this would be needlessly expensive and complex. The demand is an intermittent one and can easily be met by supplying a bank of high pressure cylinders which can be manifolded and bled into the chamber. In this numerical example, a bank of thirty-eight 240 cubic foot cylinders would supply sufficient gas at atmospheric pressure. Since the delivery pressure will actually be ten times atmospheric, additional cylinders would be required to 'top off' the chamber. One difficulty in this type of supply is the unavoidable temperature changes as the compressed air is admitted. As air bleeds rapidly from the supply tanks, the expansion of the remaining gas cools it. Since the process is essentially an adiabatic one, the cooling of the supply gas must be balanced by an energy transfer to the escaping gas. As this enters the test chamber and raises the pressure there, its temperature alo increases. In a typical case the temperature in a test chamber might go from 60°F. to 110°F. in a simulated dry dive to two hundred feet of sea water (14). This could be partially prevented in small chambers by running the air through refrigerator coils before sending it to the test room. In very high pressure applications the expected rise should be calculated lest the heating unduly disturb test animals or equipment.

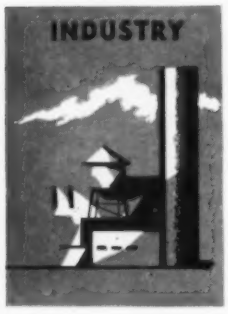
The opposite occurs during blowdown, for now the gas remaining in the room cools during expansion and mist may form, much as it does in the physicist's cloud chamber. This will almost always occur if men have been breathing into the test chamber for any length of time, for their breath is saturated with water.

The metabolic requirements of the test subjects as regards oxygen supply can be met in one of three ways. The supply technique having the most flexibility in test and medical applications is the face mask method. The subjects wear individual masks which are supplied with respirable gas from tanks outside the chamber. This supply method is economical as to gas demand and permits the attendants outside to change the gas mixture being breathed at will, a very valuable ability. The second supply method is simply a matter of continually supplying fresh gas to the chamber and venting the impure products of the body's combustion. Unless excellent gas regulating systems are used, this method will produce pressure fluctuations within the test chamber. The third supply method is to recirculate the internal atmosphere of the chamber through a chemical carbon dioxide absorbent such as soda lime (15) and add oxygen to the purified gas in sufficient quantity to make up that removed by metabolic requirements. This last technique is used in small animal experiments where the internal atmosphere of the test room can be recirculated through the carbon dioxide absorbent. In large chambers it is generally not practical to try to recirculate the internal gas since pockets will collect in corners of the test room and the carbon dioxide concentration may rise to dangerous values. Even trace amounts of carbon dioxide can have very serious effects on men and animals under high pressure.

Instrumentation of a test chamber need not be elaborate. Besides the obvious pressure regulators and gauges, the operator might require an air flow metering system to measure the subject uptake of gas, internal thermocouples or thermometers to keep track of chamber temperatures as gas is admitted or blown out, a simple gas analyzer to check the carbon dioxide concentration, lights to illuminate the test room interior, and perhaps a camera to record subject reactions.

*(Continued on Page 25)*




*if you make or test anything—*

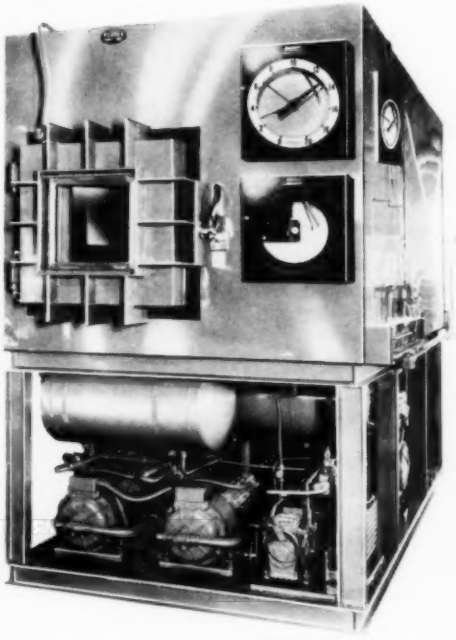
# WEBBER

# can change your environment...

If you want to simulate *altitudes to 200,000 ft.* or more; if you need to *control temperatures* from extremely low *sub-zero* to *extremely high;* if accurate *control of humidity* is vital to your test results; if *controlled cycling* of any or all of these factors is helpful to you . . . then *WEBBER is a name to remember.*

Webber environmental Test Equipment is designed and manufactured to your specifications—to help you *change your environment!*

Webber engineers *want* to be of service to you. Write now — today — and ask about Webber Field Engineering Service.



This Altitude Test Chamber was designed and built by Webber for Canadian Westinghouse to simulate altitudes to 150,000 ft., with temperatures controlled from —100 F to +250 F; Humidity from 20 to 95%. This type unit is available in sizes from small test compartments to large walk-in altitude rooms.

TRADE MARK

WEBBER

Environmental Test Equipment for use in—
Avionics Nucleonics Electronics
General Industry

**Webber Manufacturing Co., Inc.**

2740 MADISON AVE.
INDIANAPOLIS, IND.

For more information, circle No. 300, page 3.

## METHODS OF SIMULATING THE UNDERWATER ENVIRONMENT

*(Continued from Page 23)*

### SUMMARY

As is the case in most specialized fields, a survey article such as this one can only cover the most general highlights. The designer who undertakes the design of an underwater simulation chamber must satisfy himself on the mass of details that will be worked out. The wide current interest in matters pertaining to the undersea will no doubt create demands for research tools for use in testing underwater equipment of all types. Underwater television, offshore oil drilling, sport fishing and photography, oceanographic studies of fish populations, submarine and underwater demolition warfare techniques, all require varying amounts of new equipment and new ideas. We have progressed a good distance into the underwater field with very modest outlays in test equipment, but much more remains to be done before this frontier is truly penetrated.

### BIBLIOGRAPHY

(1) Paul Bert, *La Pression barometrique*, (Paris, 1878)
(2) J. S. Haldane, *Respiration*, (Yale University Press, New Haven, 1922).
(3) H. Schenck, Jr., "Physics and Physiology in Diving Decompression," (*Amer. J. Phys.*, v. 21 pp 277-280, April, 1953).
(4) Navy Dept. Bureau of Ships, *Diving Manual* (1944).
(5) Navy Dept. Bureau of Ships, *Diving Manual* (1952).
(6) Navy Dept. *Bureau of Ships Manual, Chapter 94, Section 1, Submarine Safety*, (1946).
(7) J. F. Fulton, et al, *Decompression Sickness*, (W. B. Saunders Co., Philadelphia, 1951)
(8) H. L. Maines "Aero-otitis Media in Submarine Personnel," (*J. Acous. Soc. Amer.*, v. 17, pp 139-143, October 1945).
(9) R. H. Davis, *Deep Diving and Submarine Operations*, (The Saint Catherines Press, London, 1952).
(10) R. L. Carson, *The Sea Around Us* (Oxford University Press, New York, 1951)
(11) D. Semor and C. Grove-Palmer "An Improved Technique for High Speed Photograph," (Brit. J. App. Phys., v. 3, n. 10, Oct. 1952).
(12) Argonne National Laboratory, *A Manual of Remote Viewing, ANL-4903*, (1952).
(13) *Code for Unfired Pressure Vessels*, Amer. Soc. of Mechanical Engineers, (New York, 1952).
(14) J. B. S. Haldane, "Life at High Pressures," (Science News 4, Penguin Books, 1947).
(15) H. Kendall and H. Schenck, Jr., *Shallow Water Diving*, (Cornell Maritime Press, Cambridge Md., 1950)

# New York Meeting

Sixty-five people attended the meeting of the Science Section of the New York Metropolitan Chapter on Monday, March 26, 1956, at the Engineering Societies Building. The guest speaker was Mr. John Grimm, Assistant Chief, Environmental Criteria Branch, Wright Air Force Base, Ohio. Mr. Grimm's topic was "Future Air Force Environmental Requirements."

Prior to discussing these requirements Mr. Grimm showed a film about the experimental method employed to simulate an icing environment. Heretofore, aircraft which had to be tested under icing conditions had their testing restricted to very special localities under special weather conditions, thus seriously limiting the amount of testing that could be conducted. For the sake of expediency the following method was investigated to determine its feasibility for simulating an icing environment. Briefly, this method consists of flying the aircraft to be tested at the proper altitude such that when water is sprayed on it from a flying boxcar, ice would form on the exterior parts of the aircraft being tested. Although this method does not simulate actual icing conditions, it does yield some useful information. This type of experiment will be continued to determine the modifications necessary so as to make the test more nearly simulate actual conditions.

At the completion of the film Mr. Grimm showed a series of slides that depicted actual environmental conditions aircrafts are being subjected to at various places on the globe. As a result of these environmental conditions the specifications now governing aircraft and aircraft equipment involved are being revised. Mr. Grimm pointed out that some of these specifications were too severe and would be rewritten so as to be more realistic. He also stipulated that because of the newer type of aircraft some of the limits of the test specifications covering temperature and altitude would be increased and that all future equipment should be designed to meet these higher limits. These limits may go as high as $+370°C$ and $-65°C$ for temperature and 100,000 feet for altitude. Although temperatures lower than $-65°C$ are encountered, Mr. Grimm did not expect that equipment would be required to operate below this temperature. In addition Mr. Grimm pointed out that all equipment should be studied to determine the effects upon it of radiation from nuclear powered aircraft, and the means necessary to make this equipment immune to such radiation.

# Need Testing Help?

You may find your answer here, because **Testing for Industry** has been our business for nearly 60 years. We have excellent equipment and competent, thorough, experienced men who know how to use it.

You may use our talent and facilities to supplement your own effort, or for a complete testing program. In either case, the service is independent, impartial, and as confidential as your own.

We can determine properties, characteristics, and performance of the materials, apparatus, or components you use or produce — in the following fields:

**Electrical and Electronic**
**Physical and Mechanical**
**Chemical and Environmental**

Using E.T.L. services is like finding extra trained talent and extra test equipment without adding to your payroll or capital investment.

*Know by* ETL *Test*

**ELECTRICAL TESTING LABORATORIES, INC.**

*2 East End Avenue at 79th Street • New York 21, N. Y. • BUtterfield 8-2600*

CHEMICAL • ELECTRICAL • ELECTRONIC
PHYSICAL • MECHANICAL • ENVIRONMENTAL

TESTING • INSPECTION
CERTIFICATION

INCLUDING INFRARED SPECTROSCOPY, PHOTOMETRY, RADIOMETRY, SPECTROPHOTOMETRY AND PHOTOMICROGRAPHY